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THE PRE-POTSDAM PENEPLAIN OF THE PRE-CAMBRIAN OF NORTH-CENTRAL WISCONSIN.

THE region of central and northern Wisconsin consists principally of various igneous and sedimentary rocks of pre-Cambrian age surrounded and overlapped on the southeast, south, and southwest by nearly horizontal beds of Paleozoic sedimentaries having a slight dip downward and away from the central core of the pre-Cambrian. The highest portion of the pre-Cambrian region is the divide between the waters of Lake Michigan and the Mississippi river on the south and of Lake Superior on the north. This divide lies from fifteen to thirty miles south of Lake Superior and trends in a direction slightly north of east into northern Michigan. The surface of the pre-Cambrian is gently sloping, with a more gentle inclination to the south than to the north.

The present paper describes the physiography of the southward-sloping portion of the pre-Cambrian area and particularly that part in central Wisconsin[1] in Taylor, Lincoln, Marathon, Portage, Wood, Clark, and Jackson counties which is adjacent to the Paleozoic area. A part of this section of the state is either free from drift or very sparingly covered with drift of one or more of the earlier glacial epochs, and is thus better adapted than other portions of the Lake Superior region for a study of the older non-glacial features of the land surface. The physiography of this area, including also the post-Cambrian of the southern part of the state, has been referred to by Professor Van Hise[2] in a brief description of a base-level in central Wisconsin, a reference to which is again made in a later part of this paper.

☐ *Surface feature of the pre-Cambrian.*—If one should climb the hill immediately northwest of Wausau and look eastward across the narrow valley of the Wisconsin to the flat-topped uplands, ridges, and valleys beyond, he would see that the uplands rise approximately to his own elevation and form an even crest-line along the horizon. If he should look northward, the even sky-line would be seen to rise gently but persistently to the northeast. Looking to the west, the even crests of the hills are seen to return to an elevation equal to his own. However, if he should turn to the south, Rib hill and the adjoining Mosinee hills, six miles southwest of Wausau, would rise before him and obstruct his view of the even sky-line which swings away beyond and falls not only far below the summit of Rib hill, but also much below his own position. The even-summit surface of the main upland area is the most striking feature of the landscape and at once suggests an ancient plain sloping upward to the north, below which the Wisconsin river and its tributaries have sculptured their valleys, and above which project a few isolated pointed ridges and hills like Rib hill and the Mosinee hills.

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[1] See Plate I, *Atlas of the Geology of Wisconsin*, 1881, or Plate I, *Bull. IV, Wis. Geol. and Nat. Hist. Surv.*

[2] *Science*, Vol. IV(1896), pp. 57–9.

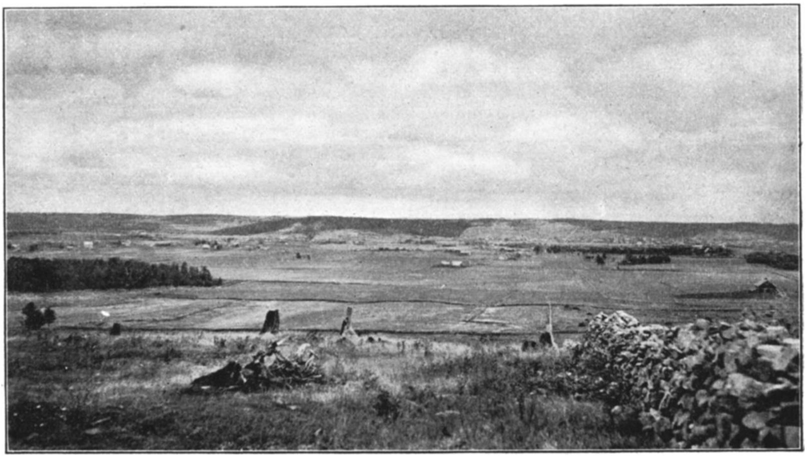

FIG. 1.—View looking east across the Wisconsin valley to the even-summited upland of the dissected peneplain. At Wausau.

Rock structure of the pre-Cambrian.—If the observer should now descend the upland and note the character of the rocks exposed along the valley sides and on the flat-topped uplands of the vicinity, he would see a wide variety of massive and schistose igneous rocks alternating with formations of metamorphic sedimentaries. Wherever the rocks are exposed, their schistosity and bedding are seen to be dipping steeply at various angles, and along the valley bottoms the streams flow over their upturned edges. Hand specimens chipped from ledges show rock crumplings on a minute scale; and the dipping beds of hillsides are the remnants of large rock folds that once roofed over broad spaces from a few hundred to a thousand feet across. Everywhere the rocks stand on edge and are folded and crumpled, and reveal a structure like that seen in the Alps, the Alleghanies, or the Rocky mountains.

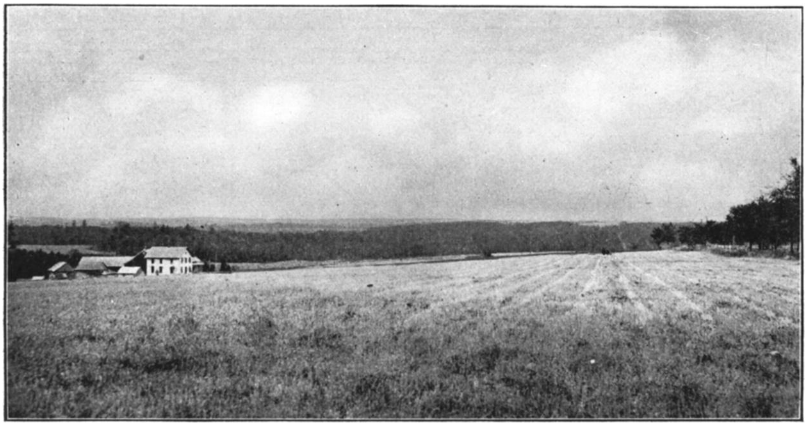

FIG. 2.—View looking west across the valley of the Little Rib river, showing the even upland of the dissected peneplain. Seven miles northwest of Wausau.

While the rocks of the pre-Cambrian area have typical mountain structures, there is nothing in the present land surface to suggest mountain topography. The dipping beds and schists stop abruptly at the even sky-line formed by the crests of the flat-topped hills. There is thus an entire lack of sympathy, a striking unconformity, between the gently sloping summits of this main upland area and the internal structure of the rocks. This indifference of surface form to internal structure could be developed in only one way; namely, by the process of degradation of a pre-existing mountainous region.

Discordance of land surface and rock structure of other regions like that of this pre-Cambrian area has been so adequately explained and so generally accepted by geologists for the last two or three decades, as the resultant of long-continued erosion, that it seems reasonable to conclude at once that the sloping, flat-topped uplands about Wausau are the remnants of what was formerly a nearly level land surface due to the wearing down by erosion of a once mountainous region to an approximate plain. The mountain folds of the pre-Cambrian have been cut off by erosion at the even sky-line of the area, just as the fibers of a great tree are cut across at the even surface of its sawed stump. The complete degradation of the mountains was not accomplished, as is evidenced by such isolated hills as Rib hill and the Mosinee hills which project above the flat-topped uplands, and

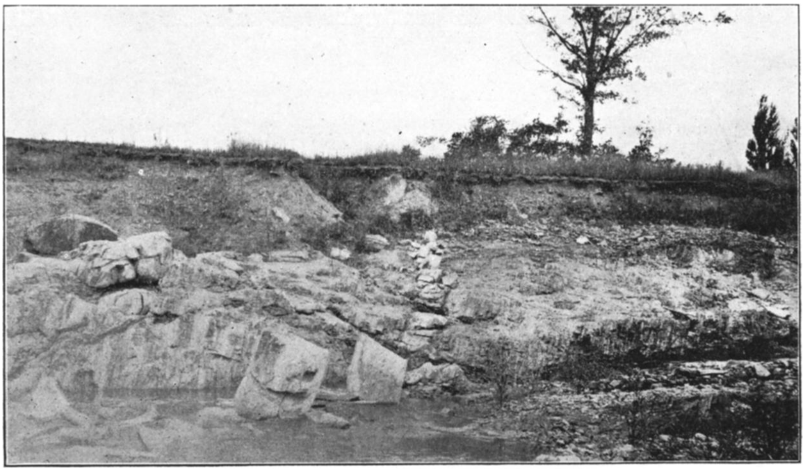

FIG. 3.—View of the beveled pre-Cambrian rocks on the west side of the Wisconsin river one mile south of Stevens Point. This is at the border of the sandstone and crystalline districts, and here the level of the river practically coincides with the level of the ancient peneplain. The view shows decomposed gneiss overlain by the river sand and gravel, the sandstone and residual clay having been eroded. On the opposite bank of the river sandstone caps residual clay, the latter grading down into the partly decomposed gneiss.

hence the region must have been, not a plain, but a peneplain of erosion.

In retrospect, the pre-Cambrian area was once a mountainous region. Subsequently the mountainous area was worn down by erosion to a peneplain, and must necessarily have been near sea-level. At a much later period the peneplain was uplifted to its present elevation, and again subjected to a period of erosion which is continued into the present time. Out of this ancient plain of erosion the present valleys about Wausau are seen to be in process of construction, and hence the region may be described as a dissected peneplain.

Present slope of the peneplain.—Since the topography of a considerable portion of this region has recently been mapped, the elevation of a part of the peneplain is definitely known. At Wausau the elevation of the dissected peneplain represented by the summits of the even-crested uplands is approximately 1,420 feet above the sea. About twenty miles north of Wausau, in the vicinity of Merrill, it is between 1,550 and 1,600 feet above sea-level. North of Merrill the thick drift of the Wisconsin Epoch is present, and the exact elevation of the pre-Cambrian is not known; but the slope upward to the north, so far as known, is about the same as it is between Wausau and Merrill. Going south of Wausau about twenty miles to the vicinity of the boundary of Marathon and Portage counties, the slope gradually descends to an elevation of about 1,200 feet, and twenty miles still farther south, in the vicinity of Grand Rapids, at the border of the Potsdam sandstone, the plain is 1,000 feet above the sea. The descent of the peneplain from seven miles north of Merrill to Grand Rapids, a distance of about sixty miles, where elevations are definitely known, is between 550 and 600 feet.

Valleys in the dissected peneplain.—The Wisconsin river from Merrill to Grand Rapids has carved a U-shaped valley with steep sides and variable width in the dissected peneplain. North of Merrill in the region of thick drift the valley is either post-glacial or much modified by glacial deposition. That part of the valley between Merrill and Wausau in the area of old thin drift has a depth of 200 to 300 feet (see Plate I, Fig. 1). The

Wisconsin valley gradually grows shallower toward the south, so that at twenty miles south of Wausau the valley bottom is only about 100 feet below the peneplain, and twenty miles still farther south, at Grand Rapids, the valley has no depth in the pre-Cambrian, but is on a level with the more rapidly descending slope of the peneplain. The branch rivers of the Wisconsin, such as the Big Rib, Big Eau Pleine, and Little Eau Pleine on hte west, and the Pine, Trap, and Eau Claire on the east, are U-shaped for about one-quarter to one-third of their distance from the Wisconsin, and then pass into narrow V-shaped valleys, and finally into broad V-shaped valleys near the flat-topped uplands. North of the branch rivers just named the drift is very thick and the side valleys, like the Wisconsin, are either wholly post-glacial or much modified by glacial action. South of these branch rivers the side valleys, like the valley of the Wisconsin, gradually grow shallower until their floors coincide with the level of the peneplain.

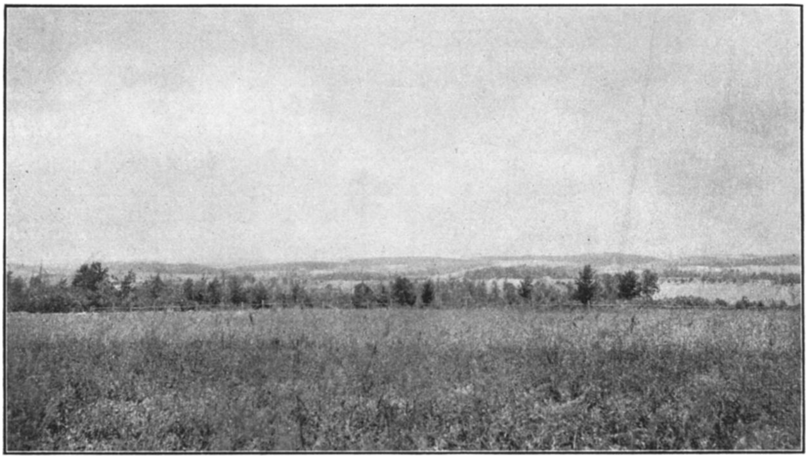

FIG. 4.—View of the dissected peneplain looking northwest one mile northwest of Wausau. The even sky-line in the distance is the ancient peneplain out of which the intervening valley of the Little Rib river has been sculptured.

The undissected portion of the peneplain.—As one goes south from the vicinity of Wausau, the dissection of the peneplain gradually grows less, and the Wisconsin valley, and also the side valleys, as already stated, gradually grow shallower, until their floors coincide with the level of the peneplain (compare Plate I, Figs. 1 and 2). Cappings of erosion remnants of Potsdam sandstone begin to appear in the slightly dissected peneplain in northern Wood and Portage counties, and become quite numerous about Grand Rapids at the border of the continuous sandstone district. For some distance into the sandstone district south of Grand Rapids, at the rapids of Grand Rapids, Port Edwards, and Nekoosa, the Wisconsin river has exposed crystalline rock, showing the latter in the river bottom and the overlying, nearly horizontal Potsdam sandstone outcropping above it in thin patches along the river bank, whence the sandstone extends in low ridgy exposures dotting the low plain of the surrounding sandstone district. The dissected peneplain about Wausau thus gradually changes to the undissected peneplain about Grand Rapids, where it is covered with thin sandstone outliers, and for some distance into the sandstone district the pre-Cambrian rocks are seen only in the river bottom, the adjacent flat-lying land being covered with Potsdam sandstone.

West of the Wisconsin river are the Yellow and Black rivers, which also lie athwart the pre-Cambrian and Cambrian districts. The Yellow in its upper course flows through the region of thick drift covering a few sandstone outliers. A short distance south of Marshfield the thick drift ceases, and from here as far south as Dexterville, a distance of twenty miles, the Yellow has exposed the pre-Cambrian in the river-bed, showing at numerous places thin cappings of the sandstone lying above it along the river bank. The descent of the pre-Cambrian surface along the Yellow river is approximately between 11 and 12 feet per mile. The Black river above Neillsville also lies in the region of thick drift and sandstone outliers, but south of Neillsville to Black River Falls—a distance of twenty-two miles—through the low plain of the thin drift area the Black shows almost continuous crystalline rocks in the river bottom, with sandstone cappings above them along the bank. The rate of descent of the crystalline area along the Black river from Neillsville, with an elevation of

996 feet, to Black River Falls, with an elevation of 812 feet, is about 9 feet per mile.

Slope of the sandstone district.— The sandstone district of south-central Wisconsin south of the vicinity of Grand Rapids and between the resistant Cambrian area on the north and the region of hard limestone rocks of the southern part of the state is preeminently a broad valley bottom plain dotted here and there with isolated peaks and mounds of sandstone. While there is considerable alluvial wash in the flat-lying sandstone district, the main features of the area, the broad plain and isolated peaks, are due to long-continued erosion. As stated by Salisbury and Atwood[1] for the vicinity of Camp Douglas: "Here the broad plain, extending in some directions as far as the eye can reach, is as low as it could be reduced by the streams which developed it." The sandstone district is therefore a graded valley plain sloping upward to the north, and isolated mounds and peaks are the disappearing remnants of divides of an earlier, less eroded sandstone region. From data of elevations along the various railroads extending across the sandstone district it is found that the slope of the valley plain is upward to the north at the rate of about 2 feet per mile. The slope upward from Kilbourn City to Grand Rapids across the entire width, north and south, of the sandstone district is only about 100 feet in about 55 miles, and thus 2 feet per mile may reasonably be considered an average slope for the sandstone district (see Plate I, Fig. 3). As already stated, from the vicinity of Merrill to Grand Rapids the southward pitch of the peneplain slope of the main pre-Cambrian area is 550 feet in 55 miles. The downward slope of the sandstone district from Grand Rapids to Kilbourn City is only about 100 feet for an equal distance of 55 miles. Thus there is an abrupt change of slope in the main land surface at the border of the sandstone and crystalline districts. The surface of the dissected plateau north of Grand Rapids is therefore not continuous in slope with the surface of the sandstone district south of Grand Rapids. On the other hand, as already shown, the beveled surface of the pre-Cambrian continues south-

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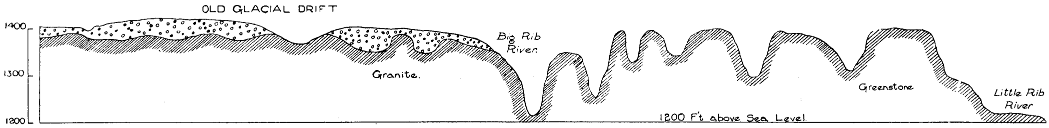
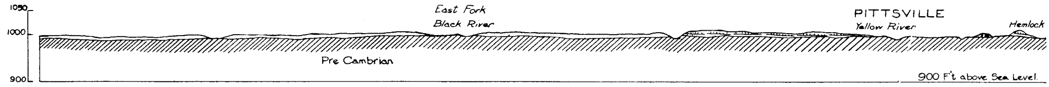
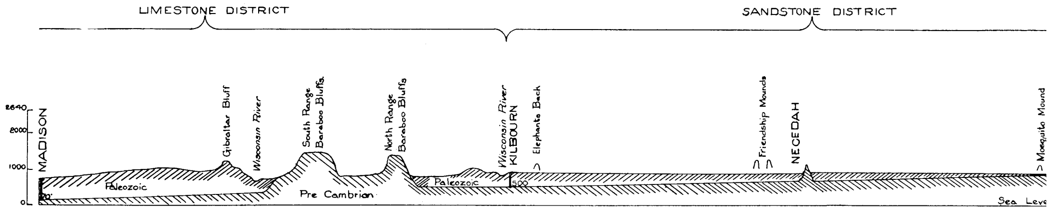
[1] *Bull. V, Wis. Geol. and Nat. Hist. Survey*, p. 51.



1. EAST AND WEST SECTION OF DISSECTED PENEPLAIN, EXTENDING THROUGH WAUSAU.

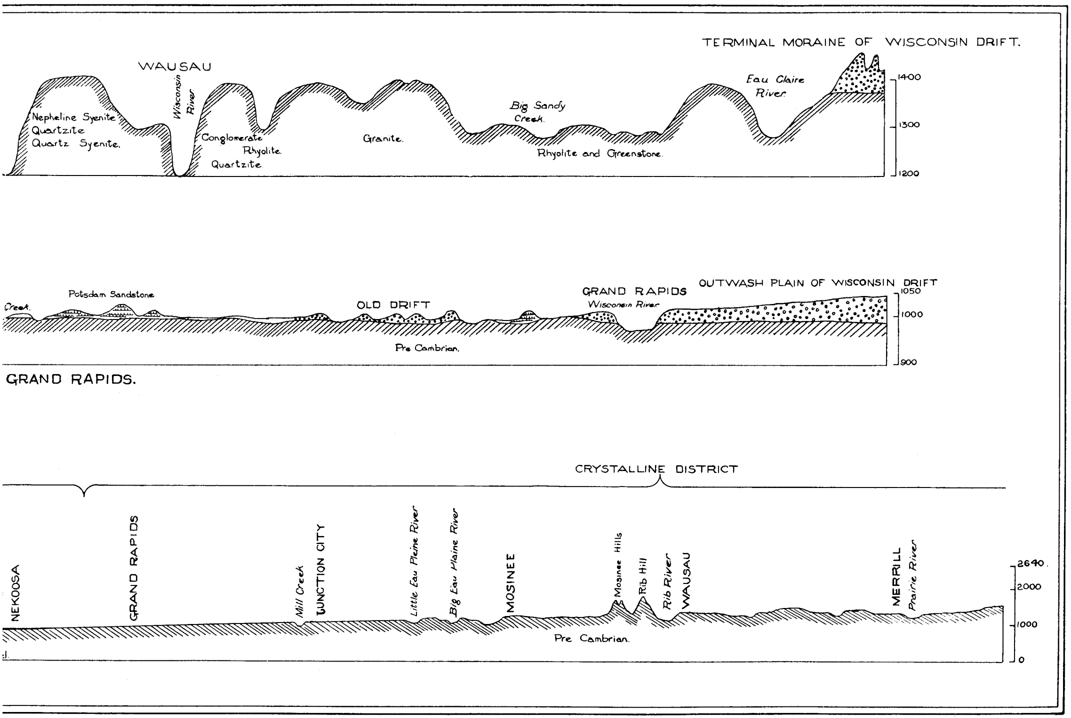


2. EAST AND WEST SECTION THROUGH PARTIALLY UNCOVERED PENEPLAIN, EXTENDING THROUGH PITTSVILLE AND



3. NORTH AND SOUTH SECTION FROM MERRILL THROUGH GRAND RAPIDS TO MADISON.

Plate I



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ward along the beds of the Wisconsin, Yellow, and Black rivers, beneath the Potsdam sandstone, in a plain sloping southward with a pitch the same as that of the peneplain farther north.

The age of the peneplain.—The deeply dissected peneplain about Wausau thus passes into the slightly dissected peneplain, covered with isolated sandstone remnants, in northern Wood and Portage counties, and at Grand Rapids, Pittsville, and Neillsville it is seen to slip under the Potsdam sandstone and become a buried peneplain (see Plate I, Fig. 3). Hence we must conclude that this peneplain was made in pre-Potsdam time.

Monadnocks in the dissected peneplain.— In our view at Wausau it was noted that certain hills and ridges project above the flat-topped uplands of the pre-Cambrian area. These are the Mosinee hills and Hardwood hill, which are conical, and Rib hill, a sharp ridge. The above-named hills consist for the most part of very coarse resistant quartzite, and for this reason they were not worn down during the general degradation of the surrounding area. These monadnocks, with their pointed crests, are in marked contrast with the flat tops of the uplands forming the peneplain. They are the remnants of a land surface older than the even-crested hills, and are typical monadnocks like Mount Monadnock of New Hampshire, which bears a similar relation to the peneplain of erosion of southern New England. Rib hill, the most prominent of these monadnocks, has a elevation of 1,942 feet above the sea and of 500 feet above the surrounding dissected peneplain. Its summit reaches over 700 feet above the alluvial plain of the Rib and Wisconsin rivers lying at its base, and it has the distinction of being one of the highest hills in the state.

Monadnocks in the slightly dissected peneplain.—About thirty-five miles southwest of Wausau at Arpin, in central Wood county, is Powers bluff, consisting of fine-grained quartzite and chert, whose elevation is not known, but which apparently reaches about 300 feet above the surrounding area of the slightly dissected peneplain. This bluff stands in the midst of isolated thin sandstone remnants lying upon the surrounding crystalline plain, and wrapped about its base are patches of Potsdam conglomerate. Powers bluff bears the same relation to the surrounding slightly dissected peneplain that Rib hill bears to the deeply dissected peneplain about Wausau. In adjacent parts of Wood county, and also in Jackson county, there are monadnocks of massive resistant granite, some of which rise from 50 to 100 feet above the general slope of the pre-Cambrian plain.

From the foregoing it has been concluded that the pre-Cambrian land was a worn-down country, a peneplain of erosion, before the Potsdam sandstone was deposited upon it, and that later it was elevated, and through the work of erosion is in the process of being uncovered and dissected. The evidence upon which the pre-Potsdam age of the crystalline peneplain is based, is the uniformity in slope of the dissected and buried portions of the pre-Cambrian land. Ordinarily such evidence as this would be deemed conclusive, and it may be so considered in this instance; but, besides the evidence of the uniformity in slope, which may be considered physiographic, there are other geological evidences in the partially uncovered portions of the pre-Cambrian area which also point clearly, it is believed, to the pre-Potsdam age of the peneplain.

Residual clay at the surface of the pre-Cambrian.— Lying at the contact of the gently sloping pre-Cambrian and the Potsdam, apparently everywhere except about the pre-Cambrian monadnocks, is a widespread formation of partly decomposed crystalline rock and clay. The clay occurs not only at the edge of the sandstone outliers and along the river banks at the margin of the sandstone district, but, as shown by a number of well-borings, it is also at various distances from these now exposed places and beneath a widely variable thickness of sandstone. The clay varies considerably in thickness, but generally has a depth of 10 to 20 feet, though in places it is known to reach the unusual thickness of 40 feet. It occurs in such abundance that it has been used quite extensively for many years for making brick, and is outlined on Dr. E. R. Buckley's map[1] of the clay deposits of Wisconsin and shown to be distributed along the boundary of the crystalline and sandstone district. It contains no evidence of sedimentation, and hence could not have been deposited by water. On the other hand, as pointed out by Irving a number of years ago,[1] there is every evidence, as shown by correspondence in structure and composition, as well as by gradation downward into the hard rock beneath, that the clay formation had its origin in the weathering and decomposition of the crystalline rocks. It was Irving's belief that the clay, though confined to the pre-Cambrian region, having more or less of a sandstone covering and often occurring beneath a few layers at least of sandstone—which fully agrees with the writer's definition of the area—had nevertheless been formed subsequent to the deposition of the Potsdam sandstone which covers it, instead of antecedent, as believed by the writer.

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[1] *Bull. VII, Wis. Geol. and Nat. Hist. Surv.*, Plate I.

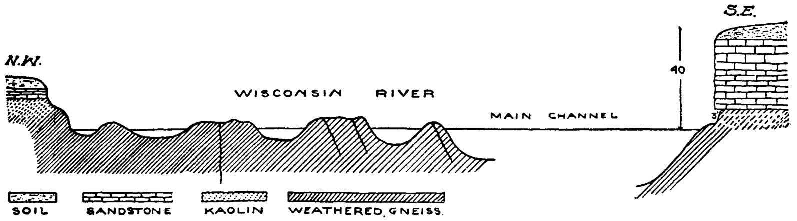

FIG. 5.—Section across the Wisconsin river valley near Grand Rapids. (After Irving.)

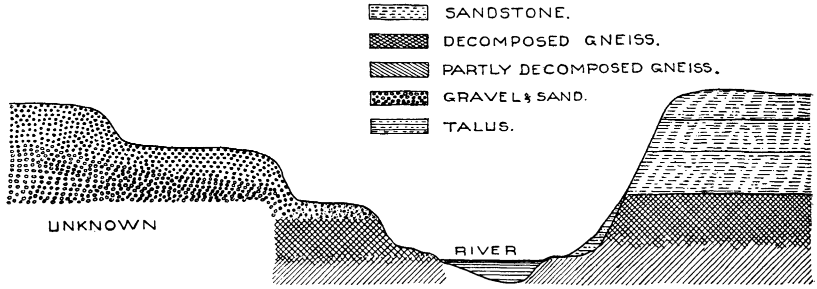

FIG. 6.—Ideal section across the Black river at Halcyon showing the shale or partly decomposed gneiss. (After Buckley.)

In the two sections, after Irving and Buckley (Figs. 5 and 6), the position of the clay beneath the sandstone is clearly shown.

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[1] *Trans. Wis. Acad. of Sci.*, Vol. II, pp. 13–17; and *Geol. of Wis.*, Vol. II, p. 468.

Immediately south of the Wisconsin Central Railway bridge at Stevens Point on the west side of the Wisconsin river relations similar to those appearing in the above sections are shown. At this place is 10 or 12 feet of decomposed pre-Cambrian rock, overlain by sandstone, along the river bank, while 40 feet west of the river is a well showing 4 feet of sandstone overlying 12 feet of clay, and 100 feet still farther west, on the west side of the wagon road, on higher ground, is a well showing 12 feet of sandstone and below this 12 feet of the kaolinized pre-Cambrian rock overlying hard crystalline rock. Similar thicknesses of the clay formation were noted beneath the sandstone mounds in which the sandstone quarries are located, on the west side of the river at Stevens Point. An instance of a sandstone mound overlying the clay is shown in the diagram (Fig. 8). About a mile north of Stevens Point is located the Langenberg brickyard, the source of the clay here used being a thickness of 15 to 20 feet of the decomposed pre-Cambrian schists. This clay-bed is about a mile and a half from the Wisconsin river and is not overlain with sandstone, though the latter formation lies at a higher level, forming a low broad hill one-fourth of a mile to the north.

It seems hardly necessary to multiply instances of the occurrence of a variable thickness of decomposed pre-Cambrian lying beneath an equally variable thickness of the Potsdam sandstone. The relations shown in the above sections are found wherever the sandstone and pre-Cambrian occur, whether it be along the river banks or in the well sections through the sandstone far from the streams.

As already stated, it was Irving's belief that the clays were formed *after* the deposition of the sandstone, two possible explanations[1] being offered by him: one, that the clays were formed by processes of weathering during the existing cycle of erosion, but mainly in pre-glacial times; and the other, that "surface waters, percolating through the porous sandstone—in ancient times much thicker than now—have formed natural watercourses along the junction between it and the less easily penetrable crystalline rocks, and have thus exerted an unusual disintegrating action; whilst the sandstone itself has subsequently acted as a preserver of the kaolinized rock from the ordinary eroding agencies." It seems hardly necessary to enter into the details of the explanations offered by Irving[1] and accepted by Buckley[2] for the post-Potsdam development of these clay deposits. It is purposed to present in a later publication a fuller discussion[3] of the clay and associated formations. It should be borne in mind that the evidence of the peneplain character of the pre-Cambrian land of central Wisconsin before the deposition of the Potsdam sandstone, which is believed to be a fact of great significance in

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[1] *Geol. of Wis.*, Vol. II, p. 464.

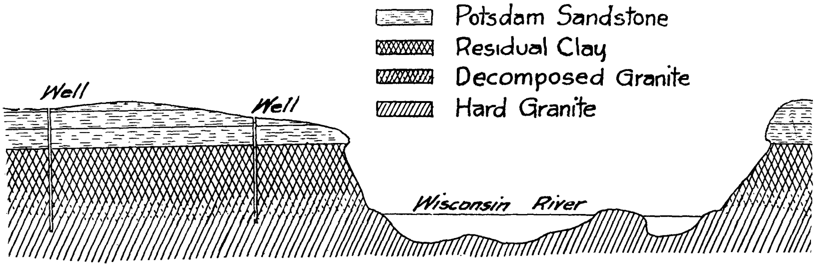

FIG. 7.—Section across the Wisconsin river at Stevens Point.

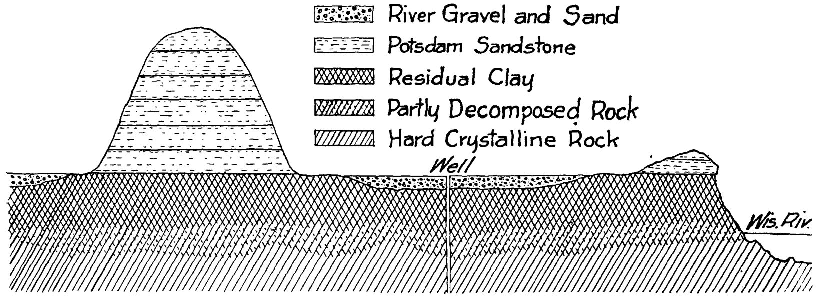

FIG. 8.—Section on west side of Wisconsin river at Stevens Point.

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[1] *Ibid.*, pp. 463, 464.

[2] *Bull. VII, Wis. Geol. and Nat. Hist. Surv.*, p. 217; also discussion before Wis. Acad. of Sci., December, 1901.

[3] A report on the geology of north-central Wisconsin, *Wis. Geol. and Nat. Hist. Surv.*

connection with the origin of the clay, was unknown to Irving. Indeed, the idea of peneplains or base-levels of erosion had hardly been promulgated at the time of his writing in 1876. While it is probable that the processes suggested by Irving may have operated to some extent in the development of the clay formation, it is not thought that either or both combined could have been important factors. It is believed by the writer that the wide-spread occurrence of the thick deposit of clay as a subjacent formation of the Potsdam sandstone obviously points to its origin and its presence there before the sandstone was deposited upon it. This view is entirely in harmony with and strongly supported by what has already been stated concerning the geographic evidence of the peneplain character of the pre-Cambrian land in pre-Potsdam time; for if the pre-Cambrian land surface were degraded to the near level of the sea, it is very evident that the conditions for deep weathering and decomposition of the surface would prevail over large portions of the plain. In the process of degradation of the pre-Cambrian, the less resistant rocks would first be cut down to the limit of slope below which the streams could not longer transport the loose material from the surface, and at this stage of the degradation, when erosion would cease, the most favorable conditions for chemical metamorphism would prevail, and the weathering and decomposition of the rock into clay would be likely to extend even to depths below the level of the sea. In fact, we could hardly expect the degrading of a land area consisting mainly of the silicate minerals like the pre-Cambrian rocks, to the near level of the sea without considerable weathering of the flat-lying surface. Hence the position of the clay beneath the sandstone, in view of the peneplain character of the pre-Cambrian land in pre-Potsdam time, obviously points, it is believed, to its development there before the deposition of the Potsdam formation.

Distribution of Potsdam conglomerate.— About the isolated sandstone outliers upon the slightly dissected peneplain, and along the crystalline rapids in the border of the sandstone district there is a general absence of conglomerate, or even a semblance of coarse sediment, at the base of the Potsdam sandstone. In the various wells also that penetrate the sandstone to the crystalline rock the clay formation generally occurs and conglomerate is rarely or never found. On the other hand, about the monadnocks in the peneplain, such as Powers bluff, which stand well within the region of outlying sandstone remnants, and about the low mounds of ferruginous schist in the vicinity of Black River Falls, there is a variable thickness of conglomerate, as would be expected. The conglomerate about the monadnocks generally, if not always, contains pebbles representing simply the quartz rock or massive granite forming the monadnocks which it lies against, and in this respect the Potsdam conglomerate is in marked contrast with the Huronian conglomerates of the region with their generally complex variety of pebbles.

Relative distribution of the pre-Potsdam clay and Potsdam conglomerate.—The distribution of the clay upon the gently sloping pre-Cambrian, as shown along the pre-Cambrian rock rapids in the border of the sandstone district, and also about and beneath the erosion remnants of sandstone upon the slightly dissected peneplain, has already been described. The occurrence of the simple conglomerate about the resistant rocks of the monadnocks is very obviously because sufficiently steep slopes existed at these places for the continuation of erosion long after the surrounding softer rocks had been reduced to a grade too low for erosion. The development of the conglomerate was very probably due to the monadnocks serving as barriers for the accumulation of coarse sediments by the waves of the Potsdam sea, in combination with stream action down the gorges and ravines of the monadnocks.

Thus the widespread occurrence of the blanket of residual clay on the gently sloping crystalline area, indicating the deep weathering of the pre-Cambrian land before the deposition of the Potsdam sandstone, as well as the distribution of Potsdam conglomerate only about the isolated monadnocks, is completely in harmony with the geographic evidence of the peneplain character of the pre-Cambrian land, and may therefore be considered as additional proof of the pre-Potsdam age of the peneplain.

Value of residual clays as evidence of unconformity.—True basal conglomerates have been quite generally used for many years by geologists as evidence of unconformity. The occurrence of residual clays or soils as evidence of unconformity has, so far as known to the writer, been used only in connection with the determining of the stratigraphy of the various Pleistocene deposits. If the explanation of the origin and age of the thick residual clays here described be the true one, and if old soils can be used as evidence of unconformity between the comparatively recent deposits of the Pleistocene series, then it seems to the writer that residual clays and soils between other unconformable series should occur, and that the presence of such residual deposits may be used as important criteria for establishing the unconformity of rock formations throughout other parts of the geological column. As formations indicating unconformity, basal conglomerates would belong to the first formation of the upper series, whereas the residual clays would be closely related to the lower series, but originating during a part or the whole of the hiatus between the deposition of the lower and the upper series. Basal conglomerates and residual clays would not likely be found in contact, but the former would be expected to be found covering hilly land surfaces and rocky coast lines, whereas the latter would be found on gentler slopes, where the forces of erosion were relatively inactive or *nil.* The fairly uniform and widespread occurrence of thick residual clays might well be considered as strong evidence of the base-leveled condition of the land floor upon which the overlying series was deposited; but isolated occurrences of such residual deposits should only be considered as an evidence of unconformity, for such isolated deposits are found at the present day in process of development in places protected from erosion, at all elevations above the sea. The full meaning of weathered zones in the stratigraphic column can therefore be understood only when considered with the associated geological phenomena.

The peneplain made by sub-aërial erosion.—Peneplains may be cut out of land areas by sub-aërial erosion—the work of rains and streams; by marine erosion—the work of sea-waves beating against a coast line; and by a combination of these processes.

In Great Britain it was formerly believed that only sea-waves could accomplish the work of reducing land areas to the near level of the sea. But the presence of the residual clay formations beneath the sandstone, indicating the deep weathering and decomposition of the pre-Cambrian surface before the Potsdam formation was deposited upon it, and the occurrence of simple conglomerate about the isolated monadnocks obviously indicate that the region must have been flat-lying near to sea-level a long time before the encroachment of the Potsdam sea. Hence the sea-waves could have had little or nothing to do with the leveling of the pre-Cambrian to a peneplain, for the degradation was accomplished mainly by sub-aërial erosion long before the sea was present.

The time of the construction of the peneplain and the deep weathering of its surface.—The period of the uplift of the pre-Cambrian horizon and the construction of the peneplain of central Wisconsin, and the deep weathering and decomposition of the surface, must have occupied a long period, even as time is reckoned in geological chronology. This period is certainly somewhere between the age of the youngest rocks of the peneplain, the Upper Huronian, and the age of the sandstone overlying them, the Upper Cambrian. It seems very probable that pre-Cambrian rocks younger than the Upper Huronian, the Keweenawan, may also be included in this old peneplain on the south slope of the crystalline district, for they are abundant in the adjoining pre-Cambrian area on the north slope along the shore of Lake Superior. It seems, therefore, that this period of erosion represents the whole of the Lower and Middle Cambrian periods, and that it may also have reached back some distance into pre-Cambrian time. The physical geography of the pre-Cambrian land at the close of pre-Cambrian time and at the beginning of Cambrian time here depicted for central Wisconsin is strikingly favorable for the conditions governing the concentration of much of the abundant iron ores[1] in other parts of the pre-Cambrian area of the Lake Superior region. These ore deposits are viewed by

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[1] "The Iron-Ore Deposits of the Lake Superior Region." *Twenty-first Ann. Rept. U. S. Geol. Surv.*, 1901, Part III, p. 330.

Van Hise as products of weathering, thus having an origin somewhat similar to these residual clays, but formed a short distance below the land surface, being "regarded as the result of the work of descending waters combined with progressive denudation."

Probable slope of the buried pre-Cambrian.—It will at once be seen by the reader that, if, as believed by the writer on the evidence here presented, the pre-Cambrian land of north-central Wisconsin is an old peneplain of erosion formed in the period preceding the deposition of the Potsdam sandstone, it is extremely probable that this peneplain has a wide extension beyond the border of the area here described. It is not the purpose of the writer, however, to present in this paper the various evidences for the belief in the wide extension of the pre-Potsdam peneplain over the pre-Cambrian land. It might be of interest, however, to point out as briefly as possible the general slope of the surface of the pre-Cambrian beneath the adjacent area of the Paleozoic rocks. It may be sufficient to state that fifty-five miles south of Grand Rapids, at Kilbourn City, as shown in Plate I, Fig. 3, the pre-Cambrian surface is struck at a depth of 385 feet, or 515 feet above sea-level. About thirty-five miles farther south, at Madison, the pre-Cambrian occurs at a depth of 810 feet, or 70 feet above sea-level. In the wells at both Kilbourn City and Madison the pre-Cambrian rock struck was called a shale, and it is apparently very similar to the decomposed clayey schists about Grand Rapids. Furthermore, no conglomerate was found at the base of the sandstone. From Grand Rapids to Madison, therefore, a distance of about ninety miles, the surface of the pre-Cambrian descends from an elevation of 1,000 feet to 70 feet above the sea, and thus the slope of the buried pre-Cambrian surface to the south continues in a remarkable manner at the same rate of descent, about ten feet per mile, that is exhibited by the uncovered and dissected peneplain between Merrill and Grand Rapids (see Plate I, Fig. 3). Between Grand Rapids and Kilbourn City is the Necedah pre-Cambrian quartzite bluff with an elevation of 1,080 feet, and between Kilbourn City and Madison are the Baraboo pre-Cambrian quartzite bluffs, whose highest points reach an elevation of 1,600 feet. Surrounding the Baraboo quartzite are great thicknesses of the Potsdam conglomerate. The Necedah quartzite probably attained an approximate elevation of 280 feet and the Baraboo quartzite ranges an elevation of 1,200 to 1,400 feet above the surrounding pre-Cambrian plain. These two elevations of the pre-Cambrian surface consist of hard resistant rock and bear a similar relation, it is believed, to the surrounding buried pre-Cambrian that the Powers bluff and Rib hill quartzite monadnocks bear to the slightly dissected and deeply dissected portions of the peneplain farther north.

Southeast of the pre-Cambrian area and also southwest there is a much steeper slope to the pre-Cambrian surface, as indicated by the artesian wells at Oshkosh and La Crosse. To the southeast are the pre-Cambrian outliers of rhyolite and granite along the Fox river, which are believed to have been monadnocks in the pre-Cambrian plain.

The uplifting and consequent folding of the region which has produced the present slope of the uncovered pre-Cambrian in central Wisconsin, as well as its buried portion farther south, is outside the scope of the present paper. Briefly stated, however, as generally accepted,[1] there is a broad anticlinal extending southward from central Wisconsin into Illinois, with a corresponding synclinal depression extending under Michigan on the east and a similar one under Iowa on the west. The uniform slope of the buried pre-Cambrian at Kilbourn City and Madison and the uncovered peneplain about Wausau is thus along the anticlinal. It is believed that the buried pre-Cambrian to the east at Oshkosh and to the west at La Crosse also had a common peneplain slope, in Potsdam time, with the now exposed portion of the pre-Cambrian, and that the greater rate of descent in these directions at the present time is to be explained as the corresponding synclinals formed in the pre-Cambrian since the beginning of Potsdam time.

Contemporaneous erosion of the pre-Cambrian and post-Cambrian rocks.—The main features of the pre-Cambrian peneplain area and the sandstone district south of the pre-Cambrian area have already been pointed out. The sandstone district is apparently a graded valley plain sloping upward to the north, and the isolated mounds are disappearing remnants of the divides of an early and less eroded sandstone region. In the sandstone district the main surface feature is the plain of the valley bottom with an entire absence of the valley sides, but as one follows north along the Wisconsin river into the pre-Cambrian area, valley sides are seen to close in upon the river, the Wisconsin valley becomes narrow and is carved deeper and deeper into the peneplain toward the north. The slope of the valley plain of the sandstone district from Kilbourn City to Grand Rapids, as shown in Plate I, Fig. 3, is upward to the north at the rate of about two feet per mile; but in the pre-Cambrian district the narrow valley bottom of the Wisconsin river rises from Grand Rapids, with an elevation of 1,000 feet, to Merrill, with an elevation of 1,250 feet, as indicated in the same figure, thus showing a rate of ascent of about four and one-half feet per mile in the dissected peneplain. Throughout the course of the Wisconsin river in the pre-Cambrian district there are numerous rapids. From Nekoosa to Stevens Point across the border of the sandstone district there is a series of almost continuous rapids where the river flows southward, there being no rapids in the westward course of the river flowing parallel to the border of the two districts. North of Stevens Point the rapids are not so numerous, though extensive rapids occur at intervals of ten to twenty miles, as at Mosinee, Wausau, and Merrill. The broad valley plain of the sandstone district thus assumes a steeper gradient as it changes to the narrow Wisconsin valley, with numerous rapids, in the dissected peneplain. It is believed that the steeper gradient and narrowness of the valley of the Wisconsin, and likewise of the other valleys in the pre-Cambrian area, as compared with the same and similarly related valleys in the sandstone area, are fully explained by the greater resistance to erosion of the crystalline rock than of the sandstone; and if this be true, it would follow that the degradation of the sandstone district and the dissection of the pre-Cambrian peneplain were very probably contemporaneous. The dissection of the pre-Cambrian peneplain about Wausau, the uncovering of the buried peneplain about Grand Rapids, and the degradation of the sandstone district, it is believed, have thus gone on hand-in-hand under the same period of sub-aërial erosion, and all phases of this work of erosion may be seen as one travels from the dissected pre-Cambrian peneplain to the broad river plain of the sandstone district.

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[1] T. C. CHAMBERLIN, *Geol. of Wis.*, Vol. IV, p. 424.

Former extension of the Potsdam.—How far to the north over the pre-Cambrian land the Potsdam sandstone was once distributed is not now known. Isolated remnants of the sandstone have been found by the writer within nine miles southeast of Wausau and four miles southwest of Medford, which are points much nearer the center of the pre-Cambrian area of Wisconsin than it was formerly supposed the sandstone occurred.[1] These sandstone remnants far within the general pre-Cambrian area are hard, resistant, consolidated rocks, which would seem to indicate that the beds now remaining were once covered over with a considerable thickness of sandstone in order to be thus consolidated. It seems not unlikely, therefore, that a great part of the ancient peneplain of the pre-Cambrian land, perhaps the whole of it, was once covered with the sandstone formation and that the sandstone has since been removed by erosion.

When Van Hise[2] wrote his brief sketch on the base-level features of this region, it was his belief that the sloping sky-line of the dissected peneplain of the district about Wausau was continuous with the tops of certain sandstone buttes in the Potsdam district, and probably with the limestone uplands of southern Wisconsin, and that, though the pre-Cambrian land may have been degraded to a low slope before the deposition of the Potsdam formation, it had later been degraded, perhaps in Cretaceous time, to form a continuous peneplain across the Paleozoic and pre-Cambrian formations. It is the thesis of the present paper that the clear-cut peneplain of the pre-Cambrian region is buried beneath the surrounding Potsdam sandstone, and therefore lies at the base of the sandstone buttes in the sandstone district and not at their tops. Professor Van Hise has since intimated his belief in the probability of the principal conclusion concerning the age of the peneplain as here presented. Whether the tops of the buttes in the sandstone district represent a Cretaceous or any other post-Paleozoic peneplain I shall not discuss. But in the pre-Cambrian region studied, although this part of the continent must have been near sea-level several times since Potsdam time, there appears to be no evidence for the belief in the degradation of the pre-Cambrian rocks to a peneplain later than the period immediately previous to the deposition of the Potsdam sandstone.

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[1] Plate I, *Atlas of the Geology of Wisconsin*, 1881.

[2] *Science*, Vol. IV (1896), pp. 57–9.

SUMMARY.

In the pre-Cambrian area of north-central Wisconsin the main feature of the land surface is the even-summited, flat-topped upland area forming an even sky-line sloping upward to the north and having the appearance of a plain or plateau below which lie the valleys of the region and above which rise a few pointed hills and ridges. The rocks of the pre-Cambrian area are of various kinds of igneous formations and metamorphic sedimentaries, which are much folded and crumpled and have a typical mountain structure. The schistosity and bedding of the various formations dip in all directions, and the formations are cut off abruptly at the even sky-line of the main upland area. The indifference of surface form to internal structure shown in the plain-like feature of the upland area and the mountain structure of the rocks, can be explained in only one way: by the degradation or wearing down by erosion of a once mountainous region to an approximate plain. Hence it is concluded that the even summits of the main upland area of the pre-Cambrian district represent the surface of an old peneplain of erosion. The pointed hills and ridges consisting of hard resistant quartzite, like the Mosinee hills and Rib hill, were not worn down to the level of the surrounding flat-topped uplands consisting of softer rocks, and these stood up as monadnocks in the peneplain.

The slope of the peneplain, as shown by the elevations of the flat-topped uplands is downward to the south at the rate of ten feet per mile. The slope of the plain of the sandstone district south of the peneplain is only two feet per mile; and hence there is a distinct unconformity in the slope of the two districts. The dissection of the peneplain about Wausau is considerable, the valleys having a depth of 200 to 300 feet. Going southward toward the sandstone district, the dissection gradually grows less, and the valley bottoms in the pre-Cambrian gradually rise nearer and nearer to the level of the peneplain. At Grand Rapids, at the border of the sandstone district, the Wisconsin valley bottom is even with the peneplain, showing the sandstone along the river banks and the beveled pre-Cambrian in the river bottom. At Grand Rapids the slope of the peneplain to the north is seen to be uniform, not with the more gentle slope of the sandstone district to the south, but with the less gentle slope of the pre-Cambrian surface in the Wisconsin river bottom. Thus it is shown that the deeply dissected peneplain about Wausau changes to the slightly dissected peneplain covered with isolated sandstone remnants immediately north of Grand Rapids, and at Grand Rapids and also at Pittsville on the Yellow river and Neillsville on the Black river the peneplain is seen to dip under the Potsdam sandstone and become a buried peneplain. It is therefore concluded that the peneplain of the pre-Cambrian area is older than the sandstone; that is, it is of pre-Potsdam age.

A further evidence of the pre-Potsdam age of the peneplain is believed to be shown by the occurrence of thick deposits of clay lying beneath the Potsdam sandstone. The clay is not of sedimentary origin, but is decomposed pre-Cambrian rock, and generally has a thickness of 10 to 20 feet, sometimes attaining a thickness of 40 feet. The residual character of the clay and its widespread distribution beneath a variable thickness of sandstone, it is believed, point to its origin before the deposition of the overlying Potsdam sandstone, at a time when the pre-Cambrian land was so flat-lying, that is, so near base-level, that conditions were favorable for the deep weathering and decomposition of the pre-Cambrian surface without removal by erosion. The absence of conglomerate at the base of the Potsdam, with the exception of the conglomerate beds about the monadnocks, which are in their simple character in marked contrast with the complex variety of pebbles found in the pre-Cambrian conglomerates, is pointed out as significant evidence in full accord with all the other indications pointing to the pre-Potsdam age of the peneplain. The occurrence of the thick deposits of residual clay beneath the Potsdam sandstone, indicating the deep weathering of the crystalline rocks without erosion, and thus the approximate base-leveled condition of the pre-Cambrian land a long time before the encroachment of the Potsdam sea, is adduced as significant evidence pointing to the degradation of the pre-Cambrian land to a peneplain by sub-aërial erosion and not by submarine erosion. The occurrence of the deposits of residual clay at the surface of the pre-Cambrian rocks suggests the probability that similar residual deposits may be found between other unconformable series, and that such residual deposits may be used as evidence of unconformity in other parts of the geological column just as the old soils and weathered zones in the Pleistocene deposits are used for determining the stratigraphy of the glacial formations.

The probable wide extension of the peneplain over other portions of the pre-Cambrian area is suggested, and the continuation of the peneplain slope beneath the surrounding Paleozoic to the south is pointed out. The degrading of the sandstone district to a broad valley plain, the uncovering of the pre-Potsdam peneplain at Grand Rapids at the border of the crystalline and sandstone districts, and the deep dissecting of the uncovered peneplain farther north, about Wausau, are pointed out as contemporaneous processes, this work being continued through a long period into the present time. The probability of the former extension of the Potsdam sandstone over a large part of the peneplain of the pre-Cambrian area, if not the whole of it, is suggested.

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EXPLANATION OF PLATE I.

FIG. 1.—Profile extending approximately east and west through the deeply dissected peneplain at Wausau. The uplands rise to the same level to an elevation of about 1,400 feet representing the surface of the peneplain.

The larger stream valleys about Wausau have been carved in the peneplain to a depth of about 200 feet.

FIG. 2.— Profile extending approximately east and west through Grand Rapids and Pittsville forty miles south of Wausau at the border of the pre-Cambrian and sandstone districts. Here the pre-Cambrian is covered with remnants of the Potsdam sandstone, and the valley bottoms are broad and shallow, and have no depth in the peneplain.

FIG. 3.—Profile extending north and south through the pre-Cambrian and Paleozoic areas, from Merrill and Wausau through Grand Rapids to Madison. The elevation of the dissected peneplain at Merrill is 1,550 feet, of the partly uncovered peneplain at Grand Rapids about 1,000 feet. The buried peneplain has an elevation of 500 feet at Kilbourn and 70 feet at Madison. The dissected peneplain, the slightly dissected peneplain, and the buried peneplain have essentially a continuous and uniform slope downward to the south. Rib hill and the Mosinee hills are monadnocks in the dissected peneplain, and the Necedah and Baraboo quartzite bluffs are monadnocks in the buried peneplain. Mosquito mound, the Friendship mounds, and Elephant's Back are mounds of Potsdam sandstone in the valley-bottom plain of the sandstone district.